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13. ABSTRACT *(Maximum 200 words)*

Research in the area of matrix-based signal processing included matric theory, numerical and parallel computing, signal processing and ~~VLSI~~ implementation. Results of the research are summarized in the final report with details in the publications and proceedings issued during the course of the research.

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JOURNAL PUBLICATIONS:

1. "CORDIC arithmetic for an SVD processor," J.R. Cavallaro and F.T. Luk, Journal of Parallel and Distributed Computing, vol. 5 (1988), 271-290.
2. "Towards a computationally feasible on-line voltage instability index," A. Tiranuchit, L.M. Ewerbring, R.A. Duryea and R.J. Thomas and F.T. Luk, IEEE Transactions on Power Systems, vol. 3 (1988), 669-675.
3. "A proof of convergence for two parallel Jacobi SVD algorithms," F.T. Luk and H. Park, IEEE Transactions on Computers, vol. 38 (1989), 806-811.
4. "On parallel Jacobi orderings," F.T. Luk and H. Park, SIAM Journal on Scientific and Statistical Computing, vol. 10 (1989), 18-26.
5. "Analysis of a recursive least squares signal processing algorithm," F.T. Luk and S. Qiao, SIAM Journal on Scientific and Statistical Computing, vol. 10 (1989), 407-418.
6. "Canonical correlations and generalized SVD: applications and new algorithms," L.M. Ewerbring and F.T. Luk, Journal of Computational and Applied Mathematics, vol. 27 (1989), 37-52.
7. "Computing the singular value decomposition on the Connection Machine," L.M. Ewerbring and F.T. Luk, IEEE Transactions on Computers, vol. 39 (1990), 152-155.
8. "A unified systolic array for adaptive beamforming," A.W. Bojanczyk and F.T. Luk, Journal of Parallel and Distributed Computing, vol. 8 (1990), 388-392.

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CONFERENCE PROCEEDINGS:

1. "A Novel MVDR Beamforming Algorithm," A. Bojanczyk and F.T. Luk, Proceedings of SPIE Volume 826, Advanced Algorithms and Architectures for Signal Processing II (1987), 12-16.
2. "On the Equivalence and Convergence of Parallel Jacobi SVD Methods," F.T. Luk and H. Park, Proceedings of SPIE Volume 826, Advanced Algorithms and Architectures for Signal Processing II (1987), 152-159.
3. "System identification and control using SVDs of systolic arrays," W.E. Larimore and F.T. Luk, Proceedings of SPIE Volume 880, IS&T High Speed Computing (1988), 37-48.
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5. "Computing the singular value decomposition on the Connection Machine," L.M. Ewerbring and F.T. Luk, *SVD and Signal Processing: Algorithms, Applications and Architectures*, E.F. Deprettere, Ed., North-Holland, Amsterdam (1988), 407-424
6. "Canonical correlations and generalized SVD: applications and new algorithms," L.M. Ewerbring and F.T. Luk, Proceedings of SPIE Volume 977, Real Time Signal Processing XI (1988), 206-222.
7. "A transputer implementation of system identification and control using SVD's," W.E. Larimore, D. Martin and F.T. Luk, Proceedings of SPIE Vol. 1152, Advanced Algorithms and Architectures for Signal Processing IV (1989), 108-118.
8. "The HK-singular value decomposition," L.M. Ewerbring and F.T. Luk, Proceedings of the Sixth Army Conference on Applied Mathematics and Computing, ARO Report 89-1 (1989), 881-891.
9. "Singular value computations on a massively parallel machine," L.M. Ewerbring and F.T. Luk, Proceedings of TENCON '89, Bombay, India (1989), 348-351.

BOOK EDITOR :

1. Proceedings of SPIE Volume 826, Advanced Algorithms and Architectures for Signal.Processing II (1987), SPIE - The International Society for Optical Engineering, Bellingham, Washington, 34 papers / 249 pages.
2. Proceedings of SPIE Volume 975, Advanced Algorithms and Architectures for Signal.Processing III (1988), SPIE - The International Society for Optical Engineering, Bellingham, Washington, 43 papers / 395 pages.
3. Proceedings of SPIE Volume 1152, Advanced Algorithms and Architectures for Signal Processing IV (1989), SPIE - The International Society for Optical Engineering, Bellingham, Washington, 43 papers / 507 pages.

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This project supported Professor Luk and students Joseph Cavallaro, Magnus Ewerbring, Haesun Park, Sanzheng Qiao, and David Schimmel.

Ph.D. Students supervised by Professor Luk:

Paul Chau,	"High Performance VLSI Algorithms and Architectures for Digital Signal Processing," Ph.D. in Electrical Engineering, August 1987.
Haesun Park,	"On the Equivalence and Convergence of Parallel Jacobi SVD Methods," Ph.D. in Computer Science, August 1987.
Sanzheng Qiao,	"Fast Toeplitz Orthogonalizations," Ph.D. in Applied Mathematics, August 1987.
Joseph Cavallaro,	"VLSI CORDIC Processor Architectures for the Singular Value Decomposition," Ph.D. in Electrical Engineering, August 1988.
Magnus Ewerbring,	"A New Generalization of the Singular Value Decomposition: Algorithms and Applications.," Ph.D. in Electrical Engineering, August 1989.

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BRIEF OUTLINE OF RESEARCH FINDINGS:

We worked in the area of matrix-based signal processing. Our interests span a wide spectrum from matrix theory to VLSI implementation.

On matrix theory: We developed a new generalization of the singular value decomposition, and showed how our new technique can be useful in important applications such as weighted least squares, canonical correlations, and linear prediction.

On numerical and parallel computing: We implemented our systolic singular value decomposition (SVD) gorithms on the massively parallel Connection Machine, and obtained a very encouraging linear time behavior. Our other significant result is a new implicit algorithm for finding a singular value decomposition of a product of three matrices.

On signal processing: We analyzed an important recursive least squares signal processing algorithm, and showed that, contrary to popular belief, the computed result may contain huge numerical errors when the given data matrix is ill-conditioned. We also developed a systolic algorithm for adaptive beamforming. Unlike previous work by other researchers, our new algorithm can be implemented on a single systolic array. We have thus greatly improved on the efficiency of the systolic beamforming algorithm, because we need not worry about the high communication cost at the interfacing of different systolic arrays.

On VLSI implementation: We studied various ways to build an SVD engine using VLSI technology, and concluded that the CORDIC approach offers the best compromise in terms of area and speed tradeoff. My former student, Joseph Cavallaro, is continuing the work under NSF funding, as a faculty member at Rice University.

IMPACT OF OUR WORK

On matrix theory: Our new generalization of the singular value decomposition is being studied for possible adoption for real time control by an industrial concern.

On numerical and parallel computing: Our Jacobi scheme for finding eigenvalues is included in a library of numerical routines for the Connection Machine to be released by the Thinking Machines Corporation.

On signal processing: We have established a close working relationship with scientists at the Royal Signals and Radar Establishment in England on our systolic algorithms.

On VLSI implementation: Our work on CORDIC has attracted much attention. Research teams at UCLA, Yale, and University of Ruhr (Germany), to name just three leading universities, have proposed ways to improve on our CORDIC SVD processor.

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